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CRUISE REPORT: SOUTH CHINA SEA UPPER SLOPE SAND DUNES PROJECT, MAY 8-14, 2013

by

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14. ABSTRACT
Under ONR sponsorship and in partnership with Taiwan, a field project to investigate the effects of the large amplitude sand dunes, discovered on the upper slope of the northeastern South China Sea, on acoustic signal propagation and reverberation was launched. The research is interdisciplinary in nature, coordinated and carried out jointly by ocean acousticians, physical oceanographers and marine geologists. The experimental phase of the project entails a multibeam survey of the experimental area in 2012, a pilot experiment in 2013, and the main experiment in 2014. The pilot experiment was carried out during May 8-14 using two Taiwanese research vessels, R/V OCEAN RESEARCHER 5 (OR5) and R/V OCEAN RESEARCHER 2 (OR2). The pilot experiment successfully collected the needed initial data (acoustic transmissions, ambient noise and environmental data), tested a pop-up recovery mooring design, and examined the capability of the new OCEAN RESEARCHER 5 to carry out the work. The data and information collected are critical to the scientific and technical design as well as logistical planning for the main experiment. This cruise report documents the operations during the pilot experiment and the data collected with quick-look scientific results.

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ABSTRACT

Under ONR sponsorship and in partnership with Taiwan, a field project to investigate the effects of the large amplitude sand dunes, discovered on the upper slope of the northeastern South China Sea, on acoustic signal propagation and reverberation was launched. The research is interdisciplinary in nature, coordinated and carried out jointly by ocean acousticians, physical oceanographers and marine geologists. The experimental phase of the project entails a multibeam survey of the experimental area in 2012, a pilot experiment in 2013, and the main experiment in 2014. The pilot experiment was carried out during May 8-14 using two Taiwanese research vessels, R/V OCEAN RESEARCHER 5 (OR5) and R/V OCEAN RESEARCHER 2 (OR2). The pilot experiment successfully collected the needed initial data (acoustic transmissions, ambient noise and environmental data), tested a pop-up recovery mooring design, and examined the capability of the new OCEAN RESEARCHER 5 to carry out the work. The data and information collected are critical to the scientific and technical design as well as logistical planning for the main experiment. This cruise report documents the operations during the pilot experiment and the data collected with quick-look scientific results.

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I. INTRODUCTION

This cruise was dedicated to the life and work of Prof. David Tang, who passed away three days before sailing on May 8, 2013. He will forever be missed.

In collaboration with Taiwanese Scientists (Drs. T.-Y. Tang and C.-F. Chen of the National Taiwan University, Dr. Y.-J. Yang of the Taiwan Naval Academy, Dr. M.-H. Chang of the National Taiwan Ocean University, and Dr. L. Chiu of the National Sun Yat-sen University), an ONR-sponsored, multi-year field program was launched to characterize the large sand dunes discovered on the upper slope of the northeastern (NE) South China Sea (SCS), associated physical processes and their impact on acoustic signal propagation and reverberation. Specifically, the joint field study has the following overall scientific goals:

- To characterize the time and space scales and the distribution of large submarine sand dunes on the upper slope.
- To study the impact of the sand dunes, and the combined impact of sand dunes and nonlinear internal waves, on sound propagation, in terms of phenomenology, including anisotropic propagation characteristics, and two- dimensional (2D) and three- dimensional (3D) focusing/defocusing scattering phenomena.
- To study the associated statistics (mean, variance and coherence) of sound signal propagation over the sand dunes and their dependence on range, frequency and orientation.
- To examine the hypothesis that the internal tide and large trans- basin NLIWs are the generation mechanism of the dunes.
- To study how enhanced bottom roughness in the dune field affects transformation and energy dissipation of the NLIWs and tides as they shoal over the upper continental slope.

To enable optimal design and planning for the main experiment (scheduled for June 2014), a pilot experiment was carried out during May 8-14, 2013 to collect the preliminary and necessary environmental and acoustic data, test mooring designs and resolve logistics concerns. All cruise objectives of the pilot experiment were successfully accomplished. These include:

- Remapped the bathymetry of the experimental area with a multibeam echosounder system (MBES) on both vessels to permit an assessment of the spatial and temporal variability of the sand dune field. Note that the same area was first mapped with MBES using OR2 last year. Comparisons between this year's and last year's MBES data will provide valuable initial information on spatial and temporal changes.
- Sampled the sediment properties at peaks and troughs of the sand dunes using box cores to measure and contrast the corresponding sediment properties.
- Collected preliminary acoustic transmission and ambient noise data that are crucial to the proper design and placement of acoustic sensors and sources relative to the orientation of the sand dunes during the main experiment.
- Evaluated the capabilities of a brand new research vessel, OR5, for MBES, mooring deployment and lowered instrument package operations.
- Assessed possible mooring design and sampling technologies for a challenging

environment that has a high relief and potential temporally evolving bottom.

- Tested circular-track towed-source operation using OR2.
- Examined the physical oceanographic and acoustic conditions during May 2013.

From the acoustics perspective, the big scientific bonus during the pilot experiment was that the ocean was still in a winter condition with weak stratification and no high- frequency internal waves; thus, the data allow for an initial examination of the acoustical effects of the sand dunes alone, without the complication of NLIWs.

A. OPERATION AND CONFIGURATION

The execution of this pilot experiment involved two research vessels, OR5 and OR2. A stern view of OR5 and a deck view of OR2 are shown in Figures 1 and 2, respectively.

Figure 1. Stern view of the R/V Ocean Researcher 5, dockside in An Ping Harbor, Taiwan.

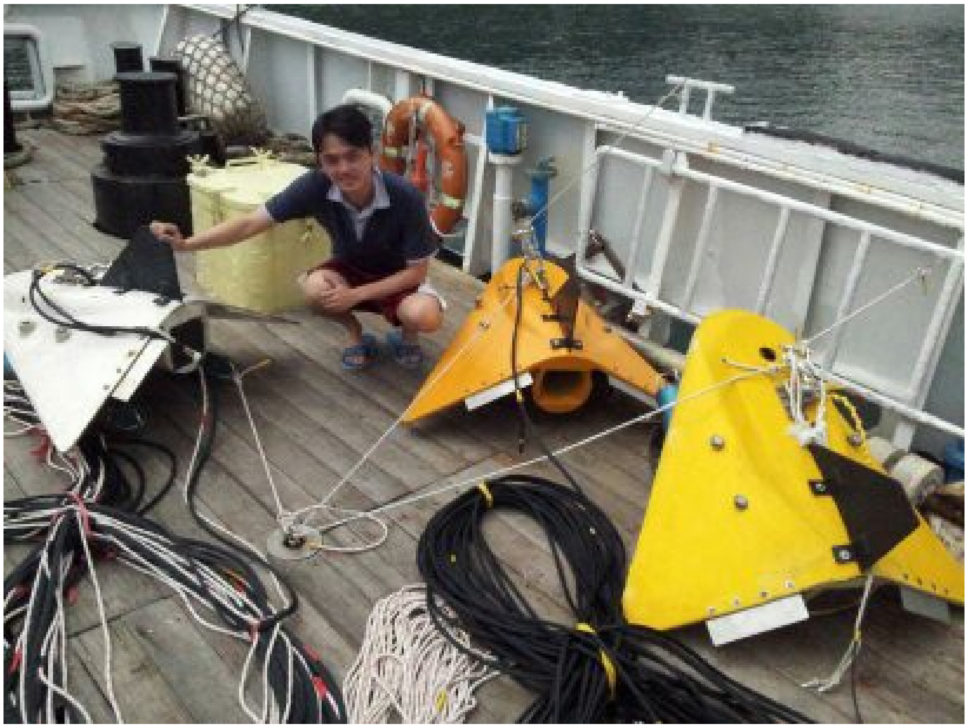

Figure 2. Deck view of R/V Ocean Researcher 2, with towed sources and Chief Scientist, Linus Chiu, on deck.

Equipped with capable A-frames and winches, OR5 was used to deploy moorings, occupy stations where a package of sensors was lowered, collect sediment samples using a box core, and perform a high- resolution MBES survey focusing on the area in the vicinity of the two moorings. The smaller OR2 was dedicated to towing a sound source transmitting acoustic signals along circular and radial tracks and performing a high-resolution MBES survey over a larger area planned for the main experiment. Drs. Y. J. Yang and L. Chiu served as Chief Scientists of OR5 and OR2, respectively. The configuration of this pilot experiment is shown in Figure 3, with the mooring locations superimposed on a screen capture of the a subset of the MBES data on OR5. A screenshot of MBES data on OR2 after her completion of the circular towed source tracks is shown in Figure 4. After towing the source, OR2 went on to carry out a MBES survey of a larger area planned for the main experiment.

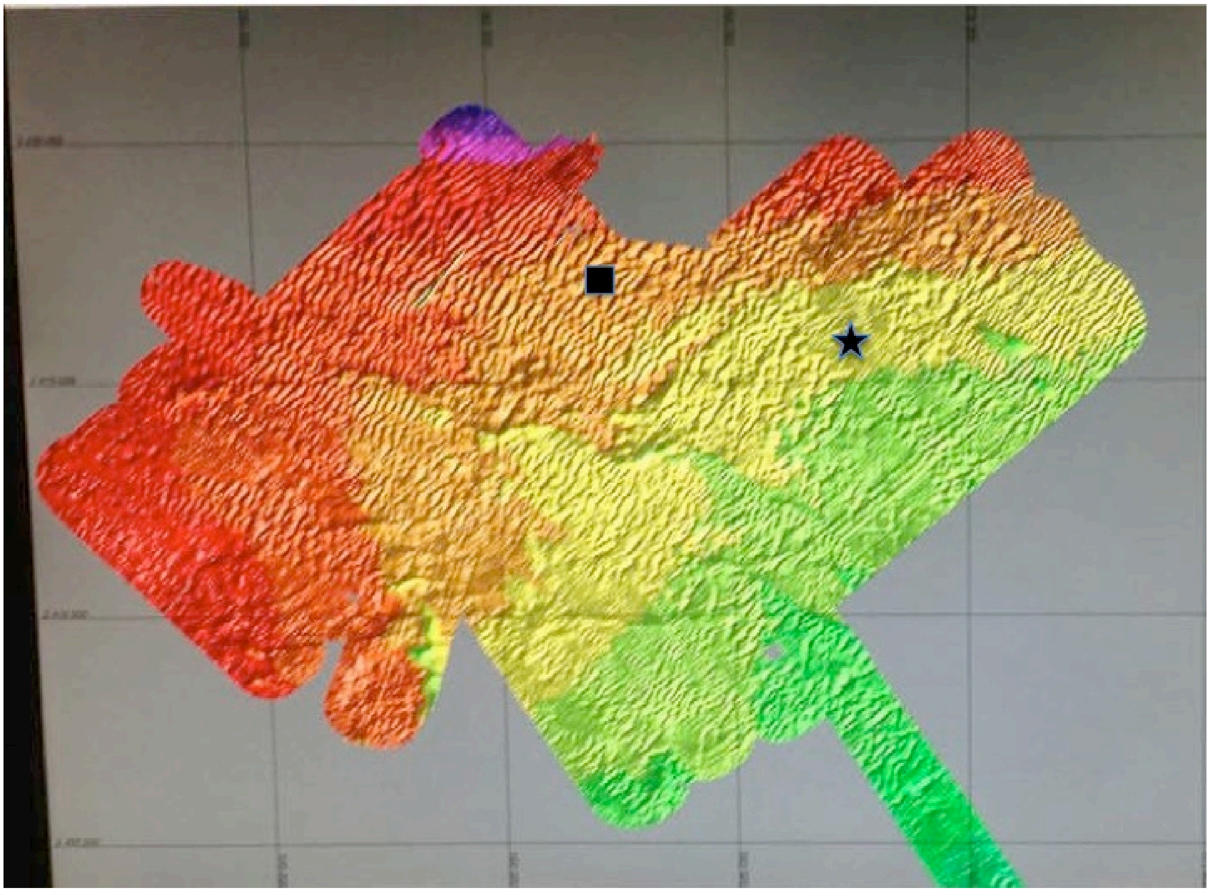

Figure 3. Screenshots of the MBES data from the OR5, May 8-14, 2013. Approximate mooring locations are shown as black star for mooring M, and black square for mooring S.

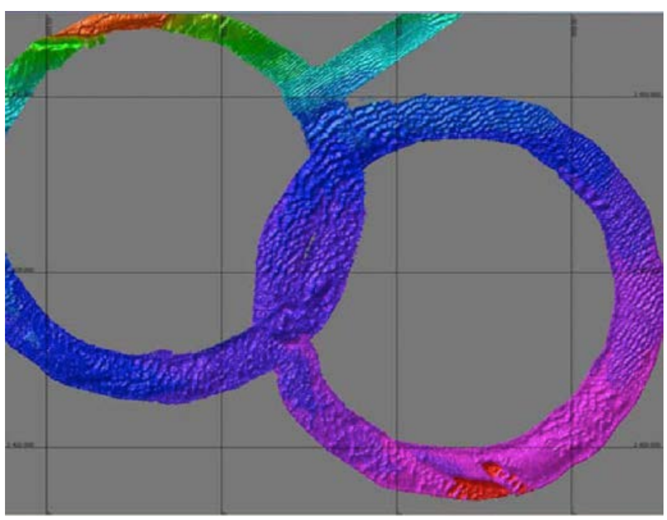

Figure 4. Screenshot of MBES data from the OR2 cruise, after completion of the circular towed source tracks.

Two moorings were deployed, one of which was designed to test a new system to place a recoverable package on the sea floor to obtain observations in the bottom boundary layer. This mooring (Figure 5, right) used a rope canister to deploy a line to the surface that could then be used to haul back the entire package. A backup release was also deployed in the event that the system failed or the bottom portion became buried in the sand by dune migration. Both moorings supported a four- element Simple Hydrophone Receiving Unit (SHRU), as well as Acousonde and/or Data Logger receivers. Both moorings were deployed at the beginning of the OR5 cruise and recovered as designed at the end. The utility of the bottom cage and anchor design for longer deployments remains contingent on determining the stability of the bottom dune field. This will be determined by comparing the MBES data from these two cruises with the MBES data from earlier cruises and planned subsequent cruises.

While the moorings were in the water, three 24- hour time series stations were conducted: one at a “smooth” location with few dunes, one at a deep location with large dunes, and one at more shallow location with large dunes. The instrument package consisted of a CTD, LADCP, transmissometer, dissolved oxygen (DO) sensor, acoustic current meter/turbulence sensor (MAVS) and a hydrophone (Figure 6). All sensors on this package worked well. One day of wave “hopscotching” was also planned, assuming a suitable wave could be observed and tracked. The plan was to position the ship in front of an advancing wave with the package deployed near the sea floor to observe the bottom interactions, then after wave passage, reposition farther up the continental shelf and repeat. In fact, no suitable wave ever appeared (see results), so this day was used for additional MBES and time series work.

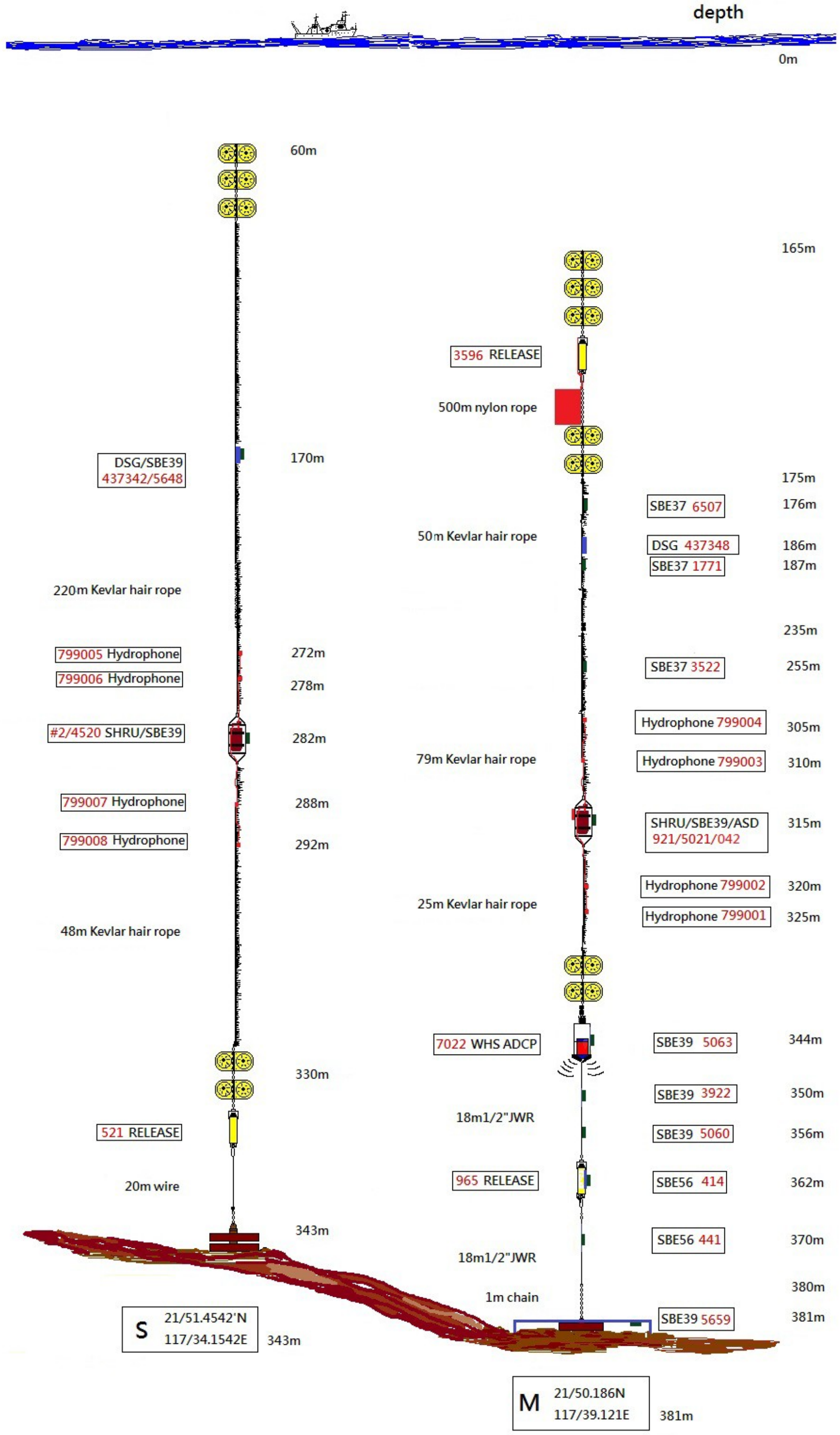

Figure 5. Schematic diagrams for moorings deployed during the Sand Dunes pilot study, May 8-14, 2013. (Diagrams drawn by Wen-Hwa Her, National Taiwan University).

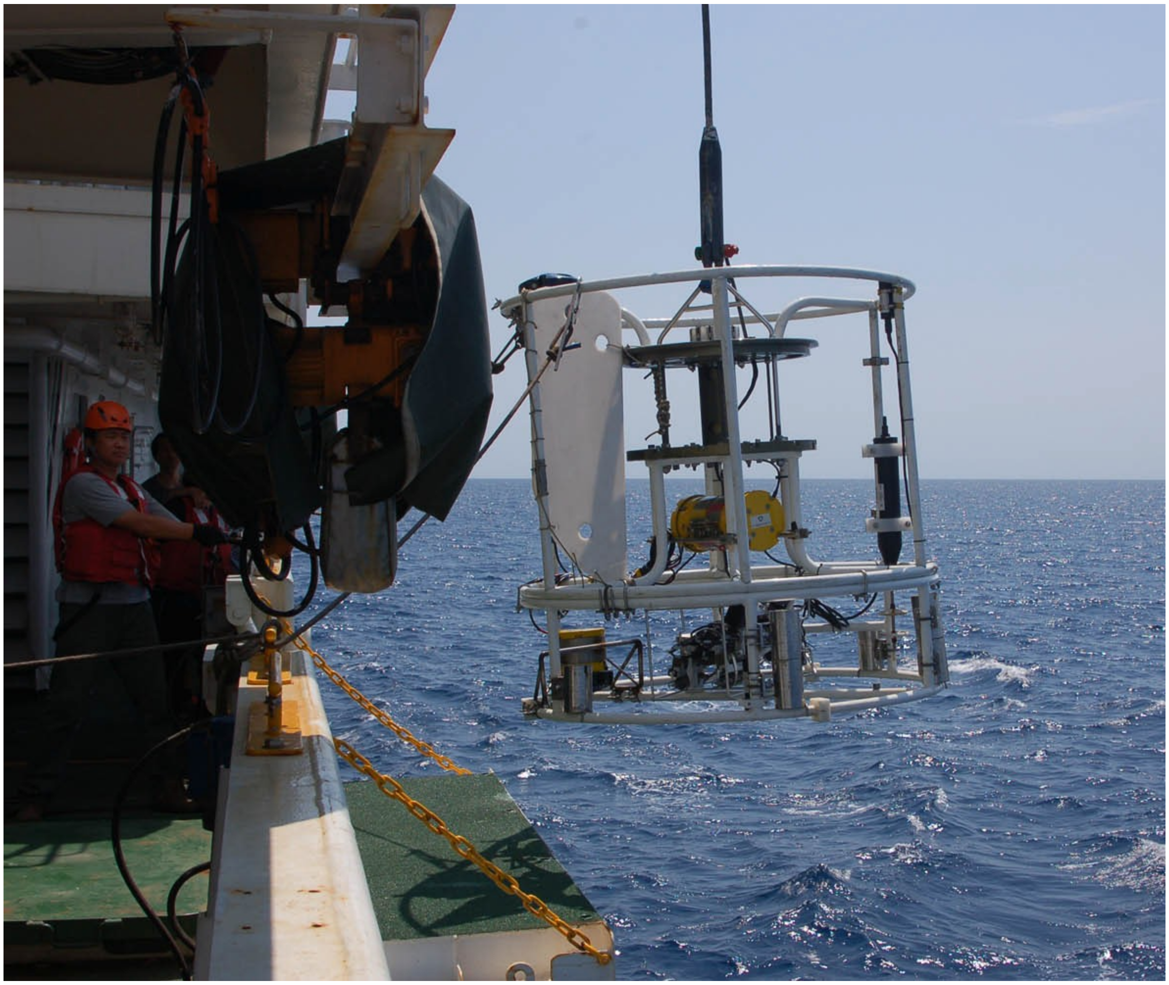

Figure 6. CTD/LADCP/MAVS package being recovered aboard the OR5. Note MAVS on the right side with white vane on the left side to orient the package into the current. LADCP units are located behind and below the vane. The Seabird CTD package is mounted near the bottom.

B. CAPABILITY ASSESSMENT OF OR5

The physical plant of the OR5 (Figure 1) is fantastic. The ship actually feels bigger than the REVELLE even though it is a little shorter, with about the same beam. This is because the bridge and superstructure are set much farther forward on OR5. There is less room on the bow, but the fantail feels at least as spacious as REVELLE. Deck machinery includes a very large stern A-frame, starboard side A- frame, two huge articulated and telescoping cranes that can reach all points on deck, a large mooring winch, a (below- decks) deep-sea coring winch, several capstans, etc. The CTD operates over the starboard side on a large hydraulic battering ram similar to the one on ATLANTIS. The CTD winch has the heaviest cable we have ever seen! Rather than Z- drives, the propulsion system consists of a single ducted screw and three thrusters, two constrained to the transverse plane through the hull and one that lowers out of the hull and can rotate 360 degrees. The dynamic positioning system works well in terms of maintaining ship position; however, it generates is noise and bubbles that degrade the performance of the hull- mounted transducers. This is problematic when DP is a must, as when threading the CTD package down between two 20-m dune crests. The staterooms are large, clean, and comfortable. We could not adequately assess how well the ship rides in rough seas since it was flat calm during our cruise.

The Taiwan Ocean Research Institute (TORI) technicians on board are very bright, hardworking, eager to learn and quickly gaining experience. We brought along three experienced technicians from National Taiwan University including the CTD tech, the ADCP tech and the mooring tech, all of whom spent considerable time training the TORI techs. This took some time but did not impact cruise goals. Importantly, after discussions and working together with the technicians, as well as seeing and actually using the A-Frame, winches, deck space and labs, we found that OR5 is very well suited for the deployment of the more complex vertical line array (VLA) receiver mooring, source mooring and environmental moorings planned for the main experiment.

C. QUICK-LOOK RESULTS

The OR2 towed a sound source in a circle of 5-km radius around each of the two moorings to provide acoustic signal propagation in different orientations with respect to the dune crests/troughs. A few radial tracks centered on the moorings were also made. On each of the two moorings, acoustic data was recorded by a four-element SHRU (Simple Hydrophone Recording Unit), Acousonde, and Data Logger receivers. The acoustic data are being analyzed for transmission loss and its anisotropy. The new Atlas MBES on OR5 worked extremely well, producing bottom maps with phenomenal detail. These maps will be essential for the placement of observational assets in the main experiment during June 2014.

The acoustic transmissions alternated between low frequency (LF) and mid-frequency (MF) linear frequency modulated (LFM) and pseudo-random noise (m-sequence) signals in the 900-2000 Hz and 4000-6000 Hz bands, respectively. Each oneminute-long transmission period consisted of 5 LFM's, one short m-sequence, and one long 45 sec m-sequence. Figures 7 and 9 show the spectrograms of 900-2000 Hz and 4-6 kHz LFM signals received by the Acousonde hydrophone on Mooring M on May 12, 2013 at 1812 and 1811, respectively. Figures 8 and 10 show the amplitudes and power spectral density estimates of the compressed pulse output (CPO) of the signals shown in Figures 7 and 9, respectively. While the towed source was most efficient in the MF band, initial analysis of the LF signals indicates sufficient SNR for reliable statistical analysis. Having acoustic data in both LF and MF bands will allow investigation of frequency- and azimuthally-dependent, sand dune-induced scattering losses.

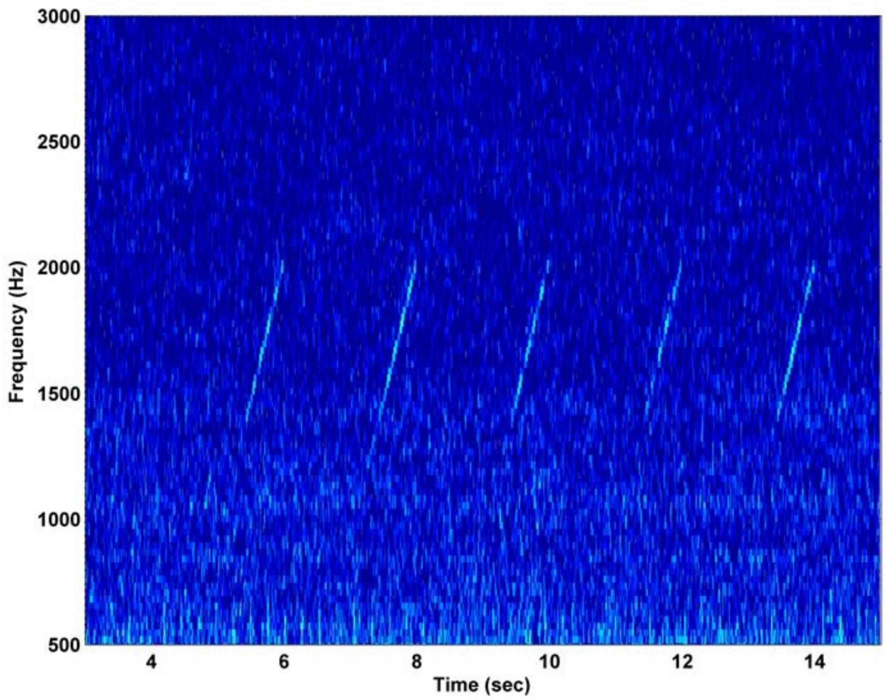

Figure 7. ***Spectrogram of 900-2000 Hz LFM signals received by the Acousonde hydrophone on Mooring M on May 12, 2013 at 1812. The signals were transmitted by a source towed by the OR2 along a circle of radius 5 km centered on the mooring.***

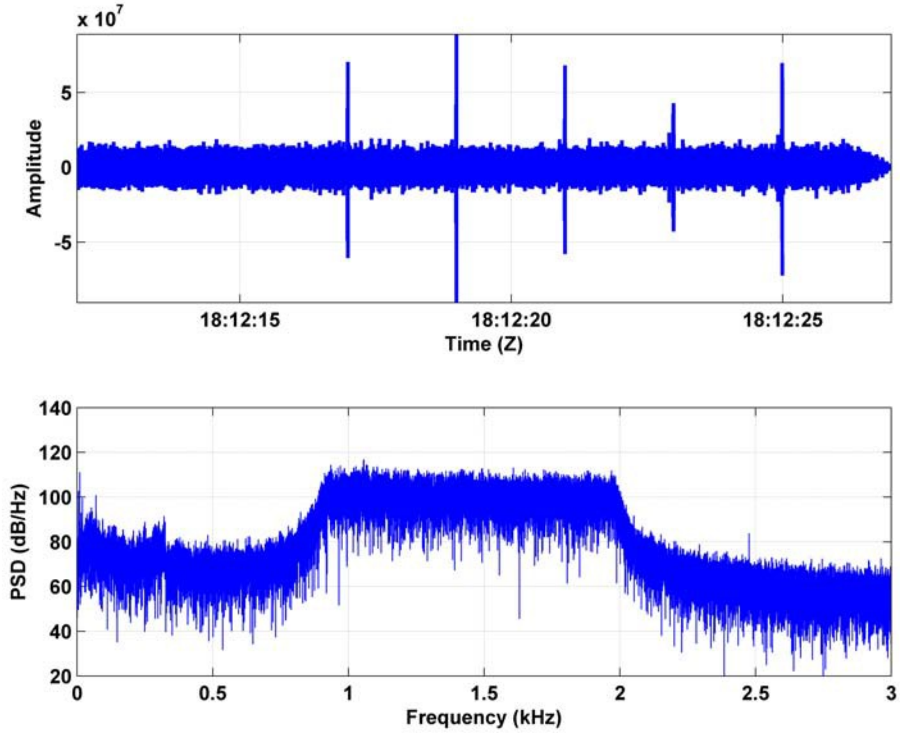

Figure 8. ***Amplitude and power spectral density (PSD) of the compressed pulse output (CPO) of the signal shown in Figure 7.***

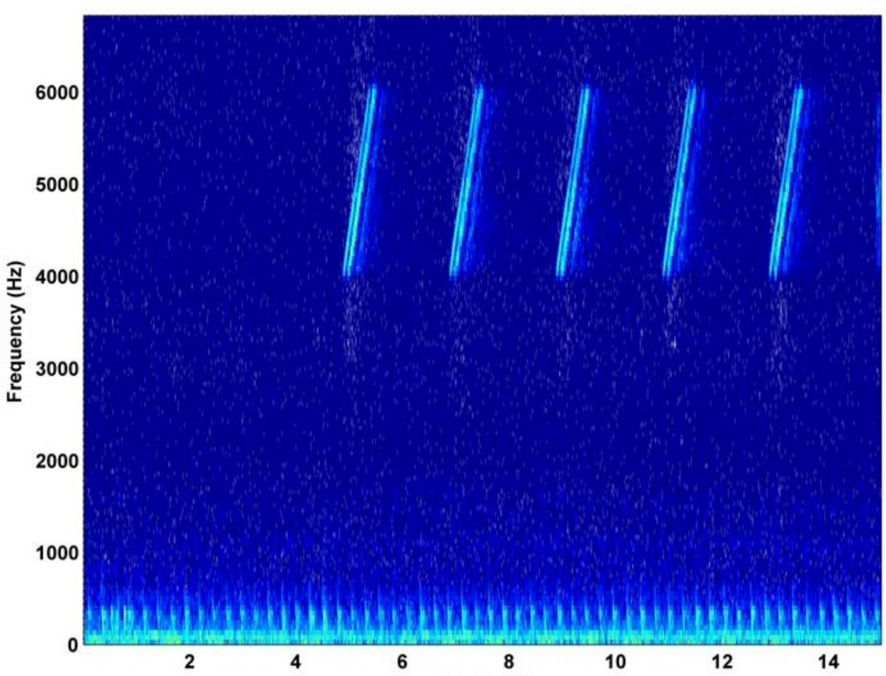

Figure 9. ***Spectrogram of 4-6 kHz LFM signals received by the Acousonde hydrophone on Mooring M on May 12, 2013 at 1811.***

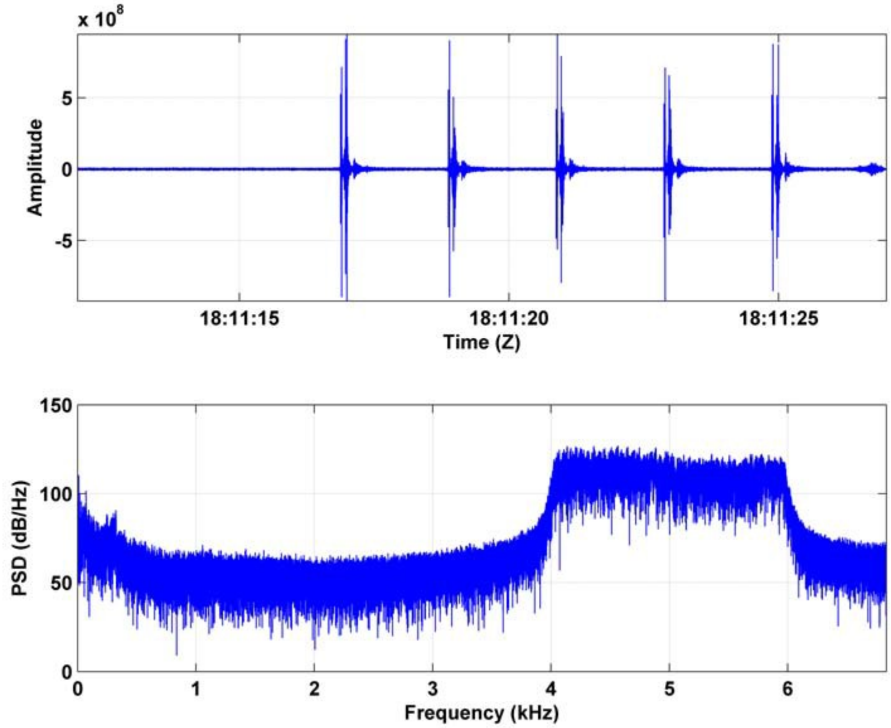

Figure 10. ***Amplitude and power spectral density (PSD) of the compressed pulse output (CPO) of the signal shown in Figure 9.***

The oceanographic results were very different from previous springs and a real challenge to decipher. During ASIAEX (May 2001) and WISE/VANS (May 2005 and 2006) which were located close by, very large solitons were observed. Large solitons were also observed at the sand dunes site during previous dune reconnaissance cruises during 2010 and 2011. During May 2013 however, despite the observations being made during a spring tide, no solitons were observed. The waves were sometimes observed in the MODIS imagery, which we were receiving in real-time, but they would then disappear before they reached the ship on the upper continental slope in around 350-400 m water depth. No solitons were ever observed at the ship and we spent much of the cruise trying to figure out why. What we did observe was rather weak but very clear mode-2 internal tides (Figure 11), which were supported by anomalous TS and stratification conditions. Relative to historical WISE/VANS data from June 2005, there was a deeper mixed layer and a weaker thermocline (Figure 12). There was also more Kuroshio water present than is normal during May, with a stronger salinity maximum near 150 m and stronger salinity minimum at depth (Figure 13). The spring rains in Taiwan were very light, and the winds were lingering out of the northeast, which is the winter monsoon condition (Joe Wang, personal communication). It seems the ocean we were observing was still the winter ocean during an anomalously late onset of the summer (southwest) monsoon. The deep surface mixed layer, weak stratification, and double thermocline structures above and below the salinity maximum, were conducive to mode-2 internal tides but not able to support incoming mode-1 solitons from the deep basin. Additional work on the mode coupling problem is underway. While we consider this condition to be highly anomalous on an inter- annual basis, we are planning to move the main field program to June 2014 to head off this situation next year.

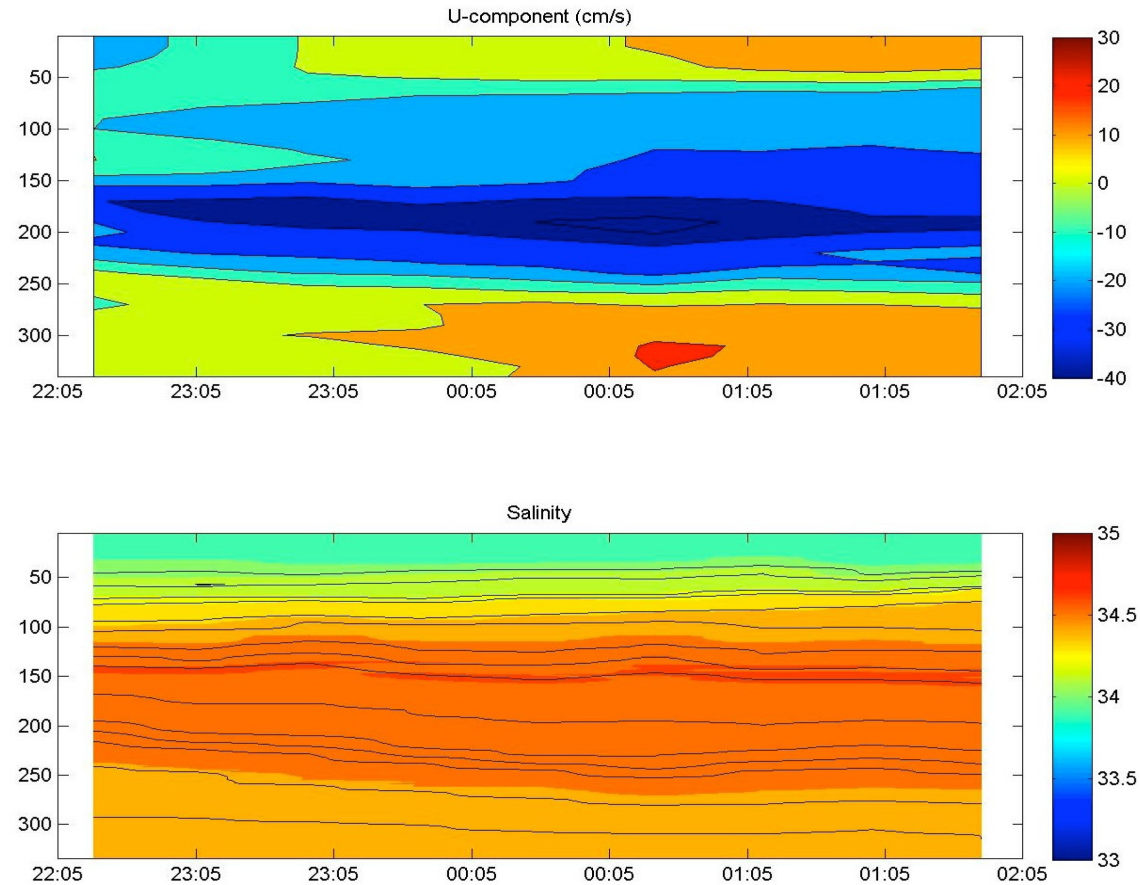

Figure 11. (top) ***The east/west component of velocity obtained using the LADCP package for a time series station near mooring S (see Fig. 4 for location). (bottom) The temperature (contours) plotted on top of salinity (color bar) for the same station. Note mid-depth bulge in both T and S associated with the westward core velocity of the mode-2 internal tide. Note also the 50 m mixed layer depth, double thermocline structure, and mid-depth thermostad.***

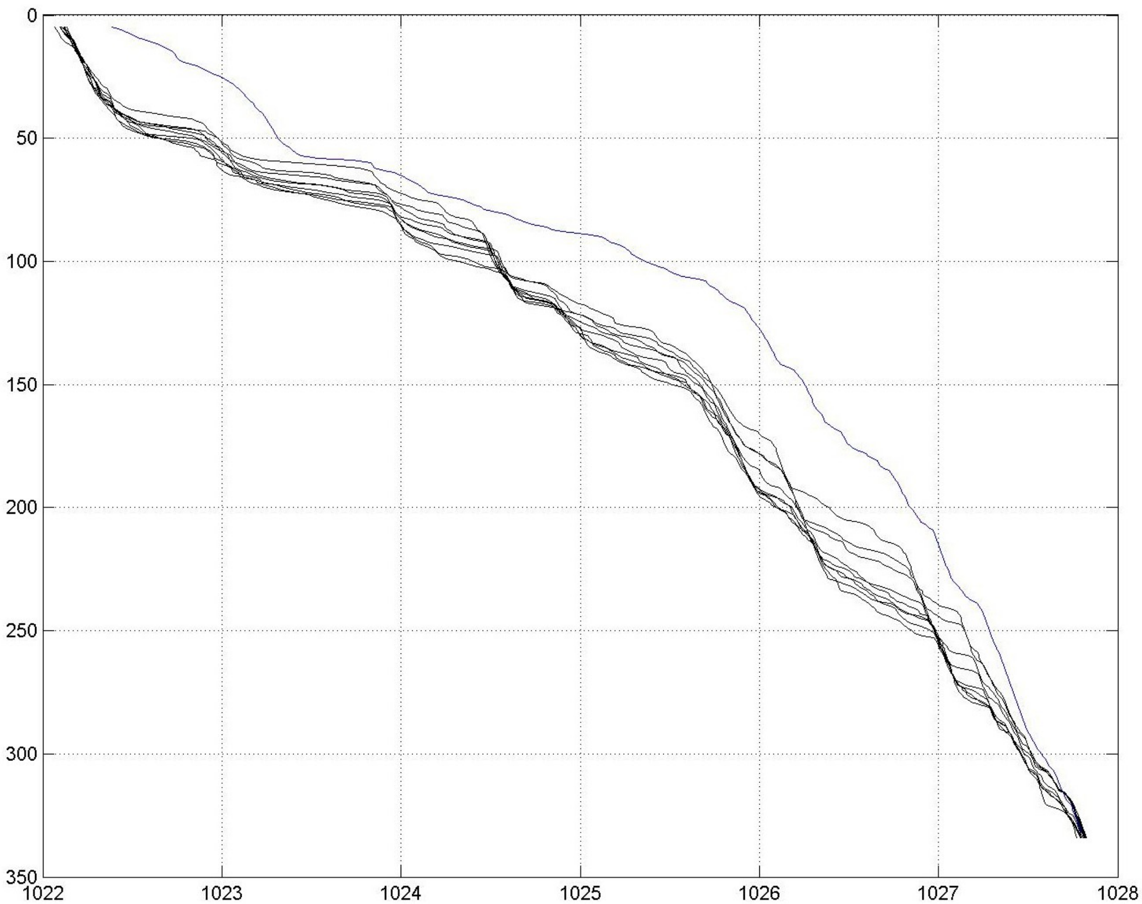

Figure 12. ***Density structure from the sand waves May 2013 cruise (color, many dots) vs. WISE/VANS data from June 2005 (solid, single line). Note the deeper mixed layer and weaker stratification during May 2013.***

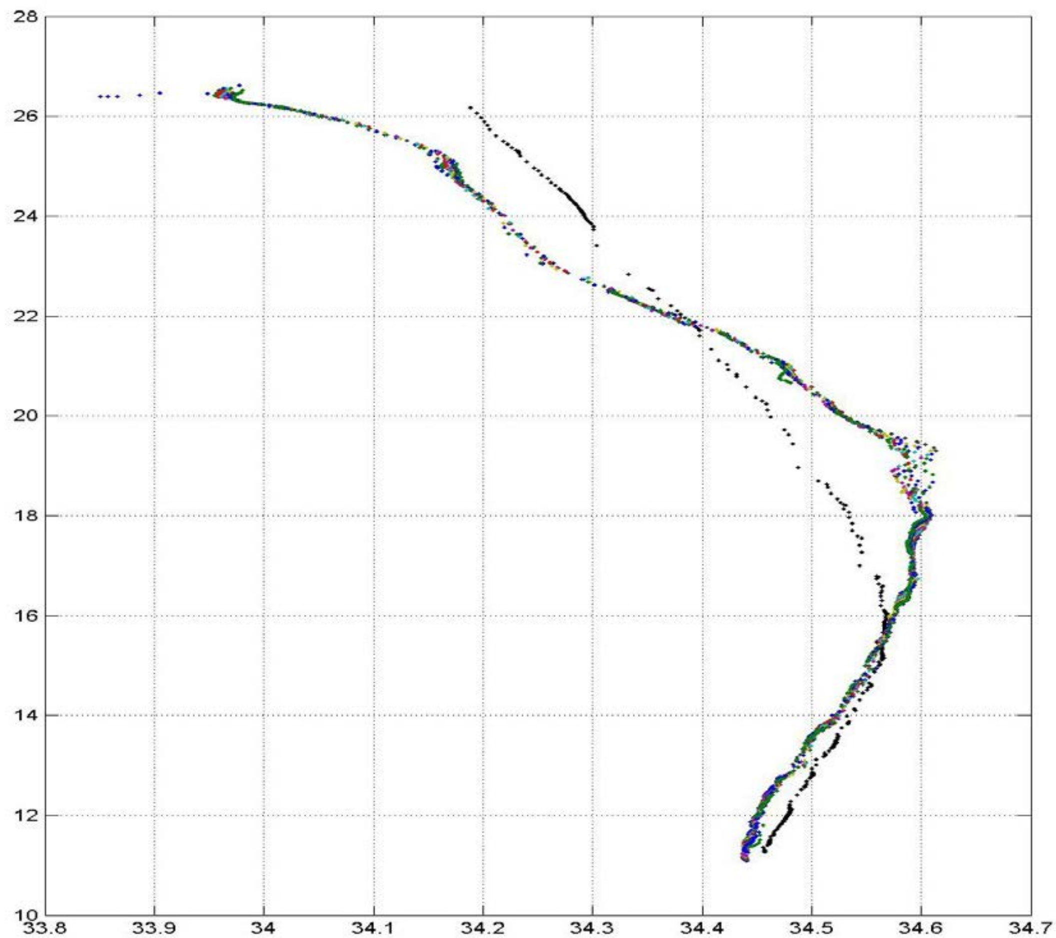

Figure 13. ***Temperature/salinity structure from the Sand Dunes May 2013 pilot cruise (color, many dots) vs. WISE/VANS data from June 2005 (black dots). Greater salinity maximum and lower salinity at depth indicate increased percentage of Kuroshio water during May 2013.***

D. PLAN OF ACTION

We had two meetings right after the OR5 cruise. The first focused on ship-time requirements and requests, and the second focused on mooring configurations and locations for the FY14 main experiment. We plan to carry out the main experiment in June to ensure a strongly stratified ocean in order to examine and contrast the acoustical effects of the sand dunes and the combined effects of the sand dunes and internal waves. We are requesting two weeks of OR5 for mooring and multibeam operations, one week of OR1 for lowered instrumentations operations, and one week of OR 3 for towed source operations. At the ship time meeting, Prof. Sen Jan of NTU, who was recently named VP of the Taiwan Ocean Research Institute (TORI) that operates OR5, indicated that the funding for ship time from their government to Taiwan's universities would be reduced by 30% next year. Given the pressurized budgetary situation, he asked us if ONR could potentially pay for up to 3 days of OR5 at a cost of $20K per day. Chiu is in communication with the ONR OA sponsor to seek guidance and a solution to this request.[1]

Processing and analysis of the MBES, box core, acoustic and oceanographic data from this pilot experiment have started in earnest, as well as the mooring design calculations for the main experiment. The data analysis will be aided with models. The next planning meeting will be held in Monterey, CA between the fall meetings of the Acoustical Society of America (ASA) and the American Geophysical Union (AGU), both of which are in San Francisco in early December. The purpose will be to review the analyzed pilot experiment results, refine the configuration for the main experiment using these results, finalize mooring designs, and formulate the multi-ship operations and schedules.

From the US side, Chiu and Ramp will be preparing four moorings (a VLA receiver, source, and an two environmental moorings) for the main experiment. From the Taiwan side, they will be preparing a total of 6 moorings. The timeline to prepare is tight. Shipment of all US equipment and mooring hardware must be done no later than March 2014. Equipment and hardware procurement, preparations, and testing must be started now and through this summer.

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[1] On June 14, 2013, Prof. Sen Jan, NTU, informed us that he has secured funding from the National Science Council (NSC) of Taiwan to cover 10 days of OR5, 6 days of OR1 and 5 days of OR3 in June 2014 for this project.

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